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# Defining a Stable, Protected and Secure Spectrum Environment for Autonomous Vehicles

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## **DEFINING A STABLE, PROTECTED AND SECURE SPECTRUM ENVIRONMENT FOR AUTONOMOUS VEHICLES**

**Robert B. Kelly\* and Mark D. Johnson\*\***

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## INTRODUCTION

Establishing a stable and secure radio-frequency (RF) environment is a key component for any system deploying autonomous vehicles and more advanced systems integrating vehicle-to-infrastructure (V2I) or vehicle-to-vehicle (V2V) communications. This is true regardless of whether the autonomous vehicle operates with existing communications systems and networks, such as Global Positioning Satellites or cellular systems, or with new systems, such as Dedicated Short-range Communications (DSRC). Parties deploying autonomous vehicle technologies and systems must navigate a complex welter of critical legal, policy, and technical issues affecting the RF spectrum upon which their systems depend.

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Spectrum allocation for private sector and state and local government usage is regulated by the U.S. Federal Communications Commission (FCC or Commission). Spectrum allocation for use by the federal government is overseen by the National Telecommunications and Information Administration of the U.S. Department of Commerce (NTIA). Other federal agencies with involvement on spectrum policy include the International Communications and Information policy group of the U.S. Department of State, and the Office of Science and Technology (OSTP) in the Office of the President. The principal congressional committees with oversight over development of spectrum policy and law include the Subcommittee on Communications, Technology and the Internet of the Senate Committee on Science, Commerce and Transportation, and the Subcommittee on Communications and Technology of the House Committee on Energy and Commerce.<sup>1</sup>

Autonomous vehicles may rely on a combination of several wireless technologies—satellite, GPS, cellular, radar and short-range communications systems, such as Dedicated Short-Range Communications (DSRC). These wireless technologies will, for example, provide turn-by-turn location information for vehicles, identify adjacent vehicles and other objects in the roadway, and transmit real-time data between vehicles and vehicles and the roadside to avoid collisions.

Each of these wireless technologies utilizes different spectrum bands, and each operates with distinct technical characteristics, procedural requirements, and limitations.

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1. In addition, the United States is a member state to the Constitution and the Convention of the International Telecommunication Union. *ITU Global Directory*, INT'L TELECOMM. UNION, [http://www.itu.int/cgi-bin/htsh/mm/scripts/mm.list?\\_search=ITUstates&\\_languageid=1](http://www.itu.int/cgi-bin/htsh/mm/scripts/mm.list?_search=ITUstates&_languageid=1) (last visited May 14, 2012). Member states to the Constitution and Convention have agreed, *inter alia*, to comply with the ITU Radio Regulations. INT'L TELECOMM. UNION CONST. pmbl. Section 4.3 of the Radio Regulations states that member states shall allocate spectrum uses that may be capable of causing harmful interference to the spectrum uses of other countries only in accordance with the table of frequency allocations included in the ITU Radio Regulations. INT'L TELECOMM. UNION, RADIO REG. § 4.3 (2008). Further, section 4.4 states that member states shall allocate spectrum in derogation of the ITU Radio Regulations and its Table of Frequency Allocations only if such allocation will not cause harmful interference to the allocations of other countries operating in conformance with the Radio Regulations and shall accept harmful interference from those conforming allocations of other countries. *Id.* § 4.4.

Given that many of these wireless technologies for autonomous vehicles will support safety applications—for example, vehicle collision avoidance—it is critical that the spectrum environment be defined with the express goal to support the needs of autonomous vehicles.

This Article examines key issues for defining the spectrum environment for autonomous vehicles and other advanced intelligent transportation systems (ITS) to reflect their unique spectrum needs. These issues include the allocation of spectrum sufficient to accommodate demand and enable growth, the assignment of spectrum to users in a manner that provides access to the necessary capacity and the management of that spectrum to maximize its utilization, and efficiency, and to ensure that autonomous vehicles may operate free from harmful interference. Public acceptance, and ultimately robust and even ubiquitous deployment, of these technologies depend upon execution of a successful spectrum strategy.

The good news for proponents of autonomous vehicle technologies is that many of the systems upon which they may depend, such as GPS, have mature, well-defined spectrum allocations. That spectrum environment, however, may not be as well defined for the specific requirements of autonomous vehicles. Changes to the spectrum landscape, such as the introduction of new or modified services in the same frequency range or even an adjacent band, may impact upon autonomous vehicles.

Section I will review current autonomous vehicle technologies, their spectrum use, and supporting wireless communications technologies, including satellite, GPS, vehicle radar, and Wi-Fi. Section II will examine existing rules, definitions, and procedures applicable to the wireless technologies that will support autonomous vehicles. Issues discussed will include: the allocation of spectrum bands for wireless services, the process of assigning spectrum rights to individual licensees, and spectrum management and interference mitigation and resolution techniques. Section III will discuss the concept of communications interoperability and supporting technical standards.

Many of the legal and policy issues that may be encountered in defining an optimal RF environment for autonomous and advanced vehicles have been encountered in

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the allocation of the 5.9 GHz band to DSRC and in the assignment of licenses to DSRC-eligibles, and in the sharing of the DSRC band with other federal and non-federal uses. However, given the early stage at which ITS usage of the DSRC band currently resides, there is limited practical experience with deployment. Accordingly, while the DSRC allocation provides the most relevant model for examination it is equally important to understand and examine potential alternative models based on other services.

## I. AUTONOMOUS VEHICLES, WIRELESS TECHNOLOGIES AND SPECTRUM USE

### A. *Autonomous Vehicles*

At the 1939-40 New York World's Fair, General Motors first exhibited the concept of radio-controlled cars that would maintain uniform spacing between vehicles.<sup>2</sup> In the intervening seventy-plus years, the development of autonomous vehicles has evolved in gradual steps as advancements in computing power and other technologies have been applied to transportation. For example, several manufacturers are currently offering "adaptive cruise control" (ACC) applications on their production vehicles.<sup>3</sup> Using lasers or radar mounted on the vehicle, alone or together, the car will maintain a set speed behind another vehicle. As the lead vehicle slows or speeds up, the ACC-equipped vehicle will follow suit. However, the driver of an ACC-equipped vehicle maintains control—with "hands on the wheel"—at all times. ACC does not employ any wireless communications between the vehicles or with the roadside infrastructure.

Another related technology that is deployed today is "lane assist" or "lane departure warning" applications that, using video, laser, and infrared sensors, warn a driver—via an audible or visible message, or even by vibrating the driver's seat—if the vehicle starts to drift out of its lane. More

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2. *The Original Futurama*, WIRED.COM (Nov. 27, 2007), [http://www.wired.com/entertainment/hollywood/magazine/15-12/ff\\_futurama\\_original](http://www.wired.com/entertainment/hollywood/magazine/15-12/ff_futurama_original).

3. *Autonomous Cruise Control System*, WIKIPEDIA.COM, [http://en.wikipedia.org/wiki/Autonomous\\_cruise\\_control\\_system](http://en.wikipedia.org/wiki/Autonomous_cruise_control_system) (last visited May 14, 2012).

advanced versions will, after a warning is provided, automatically return the car to its lane if the driver has taken no corrective action (if the driver activates the turn signal prior to changing lanes, no warning is given). As is the case for ACC, lane assist or lane departure warning applications do not take control of the vehicle away from the driver.<sup>4</sup> These applications are already offered for sale to the public on existing production vehicles.

Current autonomous vehicle technologies utilize and build on these existing applications. Prototype autonomous vehicles developed and being tested, separately, by Google and Stanford University's Center for Automotive Research (CARS), and several vehicle OEMs (BMW, Mercedes-Benz, Audi, VW, and Toyota, among others) use production vehicles equipped with advanced lasers, vehicle radars, cameras, and a GPS antenna.<sup>5</sup> The laser creates a 3-D map of the driver environment, which is then compared to a previously recorded detailed map of the driving environment using GPS. The camera and vehicle radars are used to detect potential obstacles (pedestrians, other vehicles, etc.) in the driving path. GPS is used, with add-on enhancements to increase accuracy, to determine the vehicle's location, and maintain its course on the intended driving path. Already, Google has driven its prototype Toyota Prius autonomous vehicles 140,000 miles on highways and secondary roads in California and Nevada.<sup>6</sup> On February 16, 2012, the Nevada Department of Motor Vehicles approved regulations allowing autonomous

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4. *Lane Departure Warning System*, WIKIPEDIA.COM, [http://en.wikipedia.org/wiki/Lane\\_departure\\_warning\\_system](http://en.wikipedia.org/wiki/Lane_departure_warning_system) (last visited May 14, 2012); see also NIDHI KALRA ET AL., CAL. PATH RESEARCH REPORT, UCB-ITS-PRR-2009-28, LIABILITY AND REGULATION OF AUTONOMOUS VEHICLE TECHNOLOGIES 19–22 (2009).

5. Tom Vanderbilt, *Let the Robot Drive: The Autonomous Car of the Future is Here*, WIRED.COM (Jan. 20, 2012, 3:24 PM), [http://www.wired.com/magazine/2012/01/ff\\_autonomoucars/all/1](http://www.wired.com/magazine/2012/01/ff_autonomoucars/all/1); Steve Colquhoun, *BMW's New Driverless Car Still a Decade Away*, SMH.COM.AU (Nov. 23, 2011), <http://m.smh.com.au/drive/motor-news/bmws-new-driverless-car-still-a-decade-away-20111123-1nuci.html?page=2>; Erico Guizzo, *Automaton: How Google's Self-Driving Car Works*, IEEE SPECTRUM (Oct. 18, 2011), <http://spectrum.ieee.org/automaton/robotics/artificial-intelligence/how-google-self-driving-car-works> (including embedded video).

6. John Markoff, *Google Cars Drive Themselves, in Traffic*, NYTIMES.COM (Oct. 9, 2010), <http://www.nytimes.com/2010/10/10/science/10google.html?pagewanted=all>.

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vehicles to operate in that state, the first in the nation to do so.<sup>7</sup> California<sup>8</sup> and Hawaii<sup>9</sup> are poised to be the next two states to follow Nevada's lead.

Important, expected benefits from autonomous vehicles will be the ability to significantly improve the efficiency of the roadways by increasing vehicle throughput, thus improving travel times, reducing congestion, and lessening pollution. By creating "trains" or "platoons" of vehicles traveling closely together with minimal gaps between each, it should be possible to increase roadway efficiency and realize these benefits. Proposed technical solutions for vehicle "training" or "platooning" incorporate wireless communications applications for vehicle-to-vehicle and/or vehicle-to-roadside infrastructure messaging.<sup>10</sup> In other words, vehicles traveling

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7. Mark Hachman, *Nevada Approves Rule for Self-Driving Cars*, PCMAG.COM (Feb. 16, 2012, 3:19 PM), <http://www.pcmag.com/article/0,2817,2400400,00.asp>.

8. See Autonomous Vehicles, S. 1298 (Cal. 2012), *available at* [http://www.leginfo.ca.gov/pub/11-12/bill/sen/sb\\_1251-1300/sb\\_1298\\_bill\\_20120223\\_introduced.pdf](http://www.leginfo.ca.gov/pub/11-12/bill/sen/sb_1251-1300/sb_1298_bill_20120223_introduced.pdf) (stating that this is "an act to add Division 16.6 (commencing with Section 38750) to the Vehicle Code, relating to vehicles"). This bill directed the Department of the California Highway Patrol to adopt "safety standards and performance requirements" with respect to autonomous vehicles that use "computers, sensors, and other technology and devices that enable [them] to safely operate without the active control and continuous monitoring of a human operator." Yana Welinder, *California Considers Regulation of Autonomous Vehicles*, JOLT DIGEST (Mar. 26, 2012, 5:05 AM), <http://jolt.law.harvard.edu/digest/legislation/2230>. The bill further expressly permitted the operation of such a vehicle on California roads if its manufacturer shows that the vehicle meets all the adopted requirements and standards. *Id.*

9. Relating to Motor Vehicles, H. 2238, 26th Cong. (Haw. 2012), *available at* [http://www.capitol.hawaii.gov/session2012/Bills/HB2238\\_.PDF](http://www.capitol.hawaii.gov/session2012/Bills/HB2238_.PDF) ("The director of transportation, in consultation with the insurance commissioner and the examiner of drivers of each county, shall adopt rules in accordance with chapter 91 providing for the operation of autonomous motor vehicles on highways within the State."). The House Bill was introduced January 23, 2012, and currently referred to the Senate Committee on Commerce and Consumer Protection for review March 8, 2012. *HB2238 HD1*, CAPITOL.HAWAII.GOV, [http://www.capitol.hawaii.gov/measure\\_indiv.aspx?billtype=HB&billnumber=2238](http://www.capitol.hawaii.gov/measure_indiv.aspx?billtype=HB&billnumber=2238) (displaying current status).

10. In 1997, a U.S. Department of Transportation-sponsored National Automated Highway System Consortium ("NAHSC"), which included vehicle OEMs and device manufacturers, among other stakeholders, tested the vehicle "training" or "platooning" concept at a specifically outfitted highway near San Diego, California. NATIONAL HIGHWAY SYSTEM CONSORTIUM TECHNICAL FEASIBILITY DEMONSTRATION SUMMARY REPORT (PART 1) 2 (Feb. 1998). Magnetic "markers" were placed in the roadbed to guide the vehicles as they travelled. *Id.* at 5. Sensors and communications links were used to link the



together would “speak” to one another and/or the roadside via a wireless data link to maintain the “train” or “platoon.”<sup>11</sup> The current prototype vehicles, however, are “autonomous” in the sense that they are not dependent on roadside infrastructure for their operations, nor do they incorporate vehicle-to-vehicle communications to maintain, for example, a set distance behind another vehicle. Nonetheless, the evolution of today’s prototype autonomous vehicles incorporates vehicle-to-vehicle and vehicle-to-roadside wireless communications for vehicle “training” or “platooning.” Such wireless links may also be effective in non-highway driving environments and applications, such as for collision avoidance applications at intersections, wherein vehicles use wireless links to provide warnings of sudden braking, lane changes, and the like.

*B. Wireless Communications Applications and Spectrum Use for Autonomous Vehicles*

Existing production vehicles are already equipped with a multitude of wireless communications applications, such as GPS, telematics, cellular, land-mobile, and Bluetooth. GPS, in particular, is critical for autonomous vehicles. An

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vehicles together. *Id.* at 16–17. Despite what was seen as a successful demonstration, the U.S. Department of Transportation withdrew from the NAHSC at the end of 1997, effectively cancelling the program. SUMMARY REPORT OF THE COOPERATIVE AND AUTONOMOUS WORKSHOP 27 AND 28 APRIL 1998, WASHINGTON, DC, 10 (June 25, 1998) (conducted by the National Automated Highway System Consortium for the United States Department of Transportation).

11. Research into vehicle “train” or “platoon” applications is continuing. SARTRE road-train project successfully tests four-vehicle ‘platoon,’ TRAFFICTECHNOLOGYTODAY.COM (Jan. 25, 2012), <http://www.trafficechnologytoday.com/news.php?NewsID=36190>. For example, in January 2012, the European Union’s SARTRE (“safe road trains for the environment”) project announced the successful demonstration of a multiple-vehicle platoon: a lead truck followed by three cars. *Id.* A driver operated the truck and each trailing vehicle followed autonomously at 90 km/h and with a gap of no more of 6 meters between each vehicle. *Id.* Designed not to rely on a specifically outfitted or dedicated infrastructure, the SARTRE platoon concept would operate on conventional highways and be integrated with other traffic. *How Does it Work?*, SARTRE-PROJECT.EU, [http://www.sartre-project.eu/en/faq/how\\_it\\_works/Sidor/default.aspx](http://www.sartre-project.eu/en/faq/how_it_works/Sidor/default.aspx) (last visited May 14, 2012). The trailing, autonomous vehicles employ radars, cameras and lasers, as well as a wireless communications link, to follow the lead vehicle and maintain the distance between each vehicle in the platoon. *Id.* The goal of the program is to enhance safety and reduce the environmental impact. *Id.*

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understanding of the current spectrum environment for vehicles should help define the most appropriate spectrum environment for autonomous vehicles.<sup>12</sup>

### 1. *Global Positioning System (GPS)*

GPS, or Global Positioning System, is used worldwide to provide accurate location, navigation, and tracking information. The system consists of twenty-four to thirty-two satellites in medium Earth orbit that were launched and maintained by the U.S. Department of Defense.<sup>13</sup> Since becoming fully operational in 1994, GPS use has become ubiquitous in, among others, military, civil and commercial applications. For example, virtually every smartphone sold in the world now includes a GPS receiver. GPS is also critical for managing global air traffic and for agricultural operations. GPS receivers determine their location based on timing the signals received from three to four GPS satellites. All GPS satellites broadcast at two frequencies: 1.5742 GHz and 1.2276 GHz. Autonomous vehicles rely on GPS to provide real-time, dynamic location and mapping information.<sup>14</sup>

### 2. *Commercial Wireless Services*

Similar to GPS, mobile phone usage is widespread throughout the world. The introduction of tablet devices in

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12. The following definitions would be helpful to the reader. Radiofrequency or RF refers to the range of electromagnetic waveforms that carry radio signals, from 3 kHz (kilohertz) to 300 GHz (gigahertz). JADE CLAYTON, MCGRAW-HILL ILLUSTRATED TELECOM DICTIONARY (2d ed. 2000). A “frequency” is the measure of the number of cycles of the waveform or signal per second, measured in the hertz (Hz). *Id.* One hertz is equal to one cycle in one second. *Id.* A “frequency band” or “spectrum band” are essentially used interchangeably and refer to the range of frequencies that a certain class of radio communications service operates within. *Id.* The frequency band or spectrum band may also be divided into specific channels containing a smaller range of frequencies. *Id.* “Harmful Interference” is defined under the FCC’s Rules as “Interference which endangers the functioning of a radio navigation service or of other safety services or seriously degrades, obstructs, or repeatedly interrupts a radiocommunication service operating in accordance with [the ITU] Radio Regulations (CS).” 47 C.F.R. § 2.1 (2010).

13. *Global Positioning System*, WIKIPEDIA.COM, [http://en.wikipedia.org/wiki/Global\\_Positioning\\_System](http://en.wikipedia.org/wiki/Global_Positioning_System) (last visited May 24, 2012).

14. A discussion of the potential interference to GPS receivers from LightSquared’s proposed “ancillary terrestrial service” in the satellite “L” band, which is adjacent to the GPS frequency at 1.5742 GHz is below. *See infra* Part II.A.1.ii.c.

2010 has only increased the prevalence of mobile radio devices. By the end of 2011, the number of mobile radio devices in use in the United States had exceeded the country's population of some 320 million.<sup>15</sup> Frequencies used for commercial wireless services (cellular, GSM, PCS, 3G, 4G, etc), are generally below 3 GHz. The primary bands in the United States are at 700 MHz, 800 MHz, 1.8-1.9 GHz, 1.4 GHz, 1.7 GHz, 2.1 GHz, and 2.4-2.6 GHz. GSM-standard mobile phones, used in Europe, Latin America, and elsewhere, operate in the 400 MHz, 800 MHz, 900 MHz, 1.8 GHz and 1.9 GHz bands.<sup>16</sup>

Current autonomous vehicle technologies do not appear to use cellular or other bands allocated to commercial wireless services for their operation. However, vehicle telematics applications, such as General Motors' OnStar, use commercial cellular services for the voice and data communications link between the vehicle and the call center. General Motors reports that it recently demonstrated a concept in which a driver's smartphone would communicate with the vehicle, via a wireless link, to access vehicle-to-vehicle and vehicle-to-roadside infrastructure applications, thus enabling the smartphone to interface and manage wirelessly with vehicle applications.<sup>17</sup> The advantage of this approach, according to General Motors, is that it could spur deployment of vehicle-to-vehicle and vehicle-to-roadside infrastructure applications by leveraging the existing deployed base of smartphones that consumers are bringing into their vehicles. Presumably, smartphones under this scenario could also interface with autonomous vehicles operations in the same manner.

### 3. *Vehicle Radar*

To date, several specific frequency bands have been allocated for vehicle radar devices in the United States at 17

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15. Celia Kang, *Number of Cellphones exceeds U.S. Population: CTIA Trade Group*, WASH. POST: POST TECH. BLOG (Oct. 11, 2011, 7:54 AM), [http://www.washingtonpost.com/blogs/post-tech/post/number-of-cell-phones-exceeds-us-population-ctia-trade-group/2011/10/11/gIQARNcEcL\\_blog.html](http://www.washingtonpost.com/blogs/post-tech/post/number-of-cell-phones-exceeds-us-population-ctia-trade-group/2011/10/11/gIQARNcEcL_blog.html).

16. *Cellular Frequencies*, WIKIPEDIA.COM, [http://en.wikipedia.org/wiki/Cellular\\_frequencies](http://en.wikipedia.org/wiki/Cellular_frequencies) (last visited May 14, 2012).

17. Interview with Donald Grimm, Senior Researcher, General Motors, *Telematics Update* (Mar. 21, 2012).

GHz, 24 GHz, 46 GHz, and 76–77 GHz.<sup>18</sup> Most development and deployment, both in the United States and abroad, has occurred in the 24 GHz and 76–77 GHz<sup>19</sup> bands. Shorter-range vehicle radars (“short-range radars”) are generally deployed in the 24 GHz band and longer radars (“long range radars”) in the 76–77 GHz band.<sup>20</sup> Initial vehicle radar applications included collision avoidance, parking aid and Adaptive Cruise Control, and use various radar technologies, such as ultra wideband and millimeter wave.

The prototype autonomous vehicles are equipped with vehicle radars, one for each of the four sides of the vehicle. The radars are used to identify and track the presence and movement of obstacles, particularly other vehicles present in the autonomous vehicle’s path, or found in an adjacent space.

#### 4. *Dedicated Short-range Communications (DSRC)*

Dedicated Short-range Communications (DSRC) is a short-range (less than 1000 meters) wireless service specifically created to be the wireless link for vehicle-to-vehicle and vehicle-to-roadside infrastructure.<sup>21</sup> At the request of the Intelligent Transportation Society of America (ITS America), the FCC allocated the 5.9 GHz band (5.850–

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18. See 47 C.F.R. § 15.252 (2010) (authorizing wideband vehicle radar devices in the 16.2–17.7 GHz and 23.1–29.0 GHz bands), § 15.253 (authorizing vehicle radar devices in the 46.7–47.9 GHz and 76.0–77.0 GHz). Starting in 1995, the FCC authorized vehicle radars in the 46.7–46.9, 60.0–61.0 and 76.0–77.0 GHz band. See *In re* Amendment of Parts 2, 15, and 97 of the Commission’s Rules to Permit Use of Radio Frequencies Above 40 GHz for New Radio Applications, 11 FCC Rcd. 4481 (1995). Then in 2002, the FCC authorized new ultra-wideband radio systems that, in addition, authorized vehicle radar devices in the 24 GHz band. *In re* Revision of Part 15 of the Commission’s Rules Regarding Ultra-Wideband Transmission Systems, 17 FCC Rcd. 7534 (2002).

19. Martin Schneider, *Robert Bosch GmbH, Corporate Research: Automotive Radar – Status and Trends*, in GEMIC 144 (2005), available at [http://duepublico.uni-duisburg-essen.de/servlets/DerivateServlet/Derivate-14581/Paper/5\\_3.pdf](http://duepublico.uni-duisburg-essen.de/servlets/DerivateServlet/Derivate-14581/Paper/5_3.pdf).

20. At the recently concluded 2012 World Radiocommunication Conference (WRC), the ITU passed a resolution proposing a primary allocation of the 77.5–78.0 GHz band for short-range high-resolution vehicle radars worldwide. Int’l Telecomm. Union Res. COM6/23 (WRC-12), ITU-R Radiocommunication Bureau, World Radiocommunication Conference 2012, at 2 (Apr. 3, 2012).

21. *In re* Amendment of the Commission’s Rules Regarding Dedicated Short-Range Communication Services in the 5.850–5.925 GHz (5.9 GHz Band), 19 FCC Rcd. 2458, ¶ 23, (2004) [hereinafter DSRC Rules Order].

5.925 GHz) for DSRC.<sup>22</sup> Subsequently, in 2004, the FCC enacted the technical and service rules for DSRC.<sup>23</sup> Starting in October 2004, entities were permitted to apply for and obtain licenses to operate in the DSRC service.<sup>24</sup> To date, deployment has been limited to experimental and demonstration projects.<sup>25</sup>

This service band plan includes a dedicated channel (Channel 172) for vehicle-to-vehicle communications.<sup>26</sup> Another channel (184), at the opposite end of the band, is available for longer range, higher power public safety messages, such as ambulances and fire trucks.<sup>27</sup> The service also contemplates shared use among public safety entities, commercial entities, and private vehicles.<sup>28</sup>

DSRC is intended to enable short-range wireless communications between vehicles and vehicles and the roadside infrastructure to support, in particular, safety applications, such as intersection collision avoidance. DSRC is also available for non-safety messages, vehicle diagnostics, and, commercial transactions.

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22. See *In re* Amendment of Parts 2 and 90 of the Commission's Rules to Allocate the 5.850–5.925 GHz Band to the Mobile Service for Dedicated Short-range Communications of Intelligent Transportation Services [hereinafter DSRC Spectrum Allocation Order], 14 FCC Rcd. 18221 (1999).

23. See DSRC Rules Order, *supra* note 21; *In re* Amendment of the Commission's Rules Regarding Dedicated Short-Range Communication Services in the 5.850–5.925 GHz (5.9 GHz Band), 21 FCC Rcd. 8961 (2006) (noting that this is a Memorandum Opinion and Order involving the order on reconsideration).

24. FED. COMM'N COMM'N, DA 04-3165, PUBLIC NOTICE: WIRELESS TELECOMMUNICATIONS BUREAU ANNOUNCES DETAILS CONCERNING THE LICENSING AND TRANSMITTER LOCATION REGISTRATION PROCESS FOR THE DEDICATED SHORT-RANGE COMMUNICATIONS SERVICE IN THE INTELLIGENT TRANSPORTATION SERVICE (2004). To date, forty-two public safety and private entities have received licenses. See *Universal Licensing System*, FCC.GOV, <http://wireless.fcc.gov/uls/index.htm?job=home> (last visited May 14, 2012).

25. E.g., U.S. DEP'T OF TRANSP.: RESEARCH & INNOVATIVE TECH. ADMIN., PRESS RELEASE: U.S. DEPARTMENT OF TRANSPORTATION LAUNCHES MAJOR TEST OF INNOVATIVE VEHICLE SAFETY TECHNOLOGY (2011), available at [http://www.rita.dot.gov/press\\_room/press\\_releases/rita\\_005\\_11/pdf/rita\\_005\\_11.pdf](http://www.rita.dot.gov/press_room/press_releases/rita_005_11/pdf/rita_005_11.pdf) (stating that in August 2012, and continuing until August 2013, the U.S. Department of Transportation, in conjunction with the University of Michigan, is sponsoring a—"Safety Pilot Study"—a road safety field trial in Ann Arbor, Michigan involving over 3000 vehicles to evaluate "connected vehicle" technologies, including DSRC, and help prevent accidents).

26. DSRC Rules Order, *supra* note 21, ¶ 34.

27. *Id.* ¶ 34.

28. *Id.* ¶ 5.

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Today's prototype autonomous vehicles do not incorporate vehicle-to-vehicle or vehicle-to-roadside communications. However, as discussed above, the technology may evolve to include vehicle-to-vehicle and/or vehicle-to-roadside communications for vehicle "training" or "platooning" applications. DSRC could be used to enable these applications.<sup>29</sup>

### 5. *Wi-Fi*

Wi-Fi, or wireless fidelity, is the trademarked brand name<sup>30</sup> for a technology that enables computers, tablets, smartphones, and the like, to connect to the Internet via a wireless local area network access point. Both data and voice (called Voice-over-IP) transmissions are possible. Wi-Fi certificated products and devices are based on the IEEE 802.11 wireless transmission standards. A typical access point, such as in a house, office building or a public building (such as at an airport), has a range of around twenty meters. Outdoor coverage may use a longer range.<sup>31</sup> In the United States, the 2.4 GHz band is the primary band for Wi-Fi use, although the 5.2 GHz and 5.3 GHz bands have also been allocated for wireless broadband access.<sup>32</sup>

Wi-Fi, including other wireless broadband access technologies, is considered an "unlicensed" communications service. In other words, the operator of the wireless network need not obtain an FCC license to set up and run the network. The devices themselves are first tested and certified for compliance with the applicable technical rules.<sup>33</sup> With the certification in hand, the devices can be marketed, sold, and installed by the general public without further regulatory authorization.

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29. *How does it work?*, *supra* note 11 (stating that the European Union's SARTRE project uses DSRC for vehicle-to-vehicle communications to develop a vehicle "training" or "platooning" application).

30. *Wi-Fi Certified™ Makes It Wi-Fi*, WI-FI ALLIANCE, <http://www.wi-fi.org> (last visited May 14, 2012) (stating that "Wi-Fi" is a trademark of the Wi-Fi Alliance, an industry trade group).

31. *See Wiki-Wi-Fi*, WIKIPEDIA.ORG, <http://en.wikipedia.org/wiki-Wi-Fi> (last visited May 14, 2012).

32. *Welcome*, WIMAX.COM, <http://www.wimax.com/wimax-regulatory/> (last visited May 24, 2012).

33. *See* 47 C.F.R. § 15 (2010).

In the vehicle environment, Ford announced in 1999 that it would begin equipping certain models with a Wi-Fi hotspot to provide broadband access to smartphones and other mobile devices brought into the vehicle.<sup>34</sup> There are also available after-market systems for installing a Wi-Fi hotspot in a vehicle.<sup>35</sup>

More recently, Toyota and Microsoft announced in April 2011 a partnership to develop vehicle-based “cloud computing” to provide access to applications from outside the vehicle and for the vehicle to monitor the driver’s home and other locations.<sup>36</sup> Toyota indicated that it envisions first equipping its hybrid and electric vehicles with the cloud access to facilitate home charging and energy management of its vehicles.<sup>37</sup> In September 2011, Ford introduced its “EVOS” concept car, which includes the use of a similar cloud computing application.<sup>38</sup>

#### 6. *Bluetooth*

Bluetooth is a very short-range (up to thirty feet) wireless communications technology that enables wireless devices to connect to one another without a cable, such as a computer to a printer. The technology also enables mobile phones brought into the vehicle to route in-coming and out-going calls through the vehicle, creating a hands-free wireless phone. Bluetooth is a wireless communications standard developed by an industry consortium and accepted worldwide. In the United States and Europe, Bluetooth operates at 2400 to 2483.5 MHz, divided into seventy-nine 1 MHz channels. In

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34. Lance Whitney, *Ford Cars to Become Wi-Fi Hot Spots*, CNET NEWS (Dec. 21, 2009, 8:33 AM), [http://news.cnet.com/8301-1035\\_3-10419548-94.html](http://news.cnet.com/8301-1035_3-10419548-94.html).

35. See, for example, Autonet mobile KT-ANMRTR-01 automotive Wi-Fi router (available from Amazon.com for \$104.99, plus an annual subscription fee for the wireless broadband service). *Autonet Mobile KT-ANMRTR-01 Automotive Wi-Fi Router*, AMAZON.COM, <http://www.amazon.com/Autonet-Mobile-KT-ANMRTR-01-Automotive-Router/dp/B002ACP27W> (last visited May 24, 2012).

36. Mark Hachman, *Microsoft-Toyota Telematics Partnership Based on Cloud Tech*, PCMAG.COM, (Apr. 6, 2011, 10:57 AM), <http://www.pcmag.com/article2/0,2817,2383179,00.asp>.

37. *Id.*

38. Ford Motor Co., *Ford’s Cloud-Connected Car, the EVos Concept, to Make North American Debut at 2012 CES*, PHYSORG.COM (Nov. 14, 2011), <http://www.physorg.com/news/2011-11-fords-cloud-connected-car-evos-concept.html>.

Japan, Bluetooth operates at 2472 to 2497 MHz.<sup>39</sup>

Bluetooth typically is used in vehicles to provide hands-free calling over commercial mobile systems. At this time, a role for Bluetooth in autonomous vehicles is unclear, especially given its short-range and relatively low power.

## II. LEGAL AND POLICY ISSUES FOR DEFINING THE SPECTRUM ENVIRONMENT FOR AUTONOMOUS VEHICLES

Given that autonomous vehicles will access various spectrum bands using various transmission technologies, defining a favorable regulatory environment for spectrum usage is critical. To define this environment, issues to be examined must include: (1) access and rights to spectrum, licensing concepts, definitions and eligibility; (2) spectrum sharing, management and interference resolution; and (3) technical standards. Any regulatory framework should provide sufficient flexibility to support the development and deployment of these technologies and protect from harmful interference any critical, safety-related communications that are fundamental to autonomous vehicles.

### A. *Access to Spectrum*

Spectrum is a finite and valuable resource. Current trends in wireless usage project significant growth in voice and data usage,<sup>40</sup> all of which put pressure on governments, regulators, and commercial interests to: (1) adopt policies, rules and technologies that maximize efficiencies in already available spectrum, and (2) identify new spectrum to meet increasing demand. There are several fundamental issues that define the ability for entities to access spectrum, regardless of the intended use. A first issue is the allocation of spectrum to meet demand for new services and future growth. A second issue concerns the assignment of spectrum to specific types of users, ensuring that these users have access to sufficient and reliable spectrum to meet their needs. Finally, appropriate management structures need to be put in

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39. *Bluetooth Specifications*, BLUETOMORROW.COM, <http://www.bluetomorrow.com/about-bluetooth-technology/general-bluetooth-information/bluetooth-specifications.html> (last visited May 14, 2012).

40. *Incentive Auctions*, FCC.GOV, <http://www.fcc.gov/topic/incentive-auctions> (last visited May 24, 2012).



place to maximize spectrum utility, efficiency, and cost-effectiveness.

1. *Allocation*

The FCC has the authority pursuant to Title III of the Communications Act of 1934, as amended,<sup>41</sup> to allocate spectrum for use by private, commercial, and state and local government authorities (for example, police and fire safety services). The FCC's spectrum allocation rulemakings are subject to the provisions of the Administrative Procedure Act.<sup>42</sup> The Commission, however, retains significant discretion to determine the precise course of its proceedings prescribing spectrum allocations. The FCC may adopt allocation and service rules to assign the spectrum to users in the same or separate proceedings. It may also adopt an allocation for spectrum to be held in reserve for future uses and defer any consideration of service, licensing, and technical rules.<sup>43</sup>

In May 1997, ITS America filed a petition for rulemaking with the FCC proposing that the 5.9 GHz band be made available for DSRC-based ITS services.<sup>44</sup> To support the need for the allocation, included with the petition were supporting materials addressing: existing and future DSRC applications, the National ITS Program Plan and National ITS Architecture, spectrum requirements, and international standards development, among other materials. In 1999 the FCC made its decision allocating the 5.9 GHz band to DSRC.<sup>45</sup> The process to finalize the DSRC technical and

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41. Communications Act of 1934, Pub. L. No. 73-416, ch. 652, 48 Stat. 1064 (current version at 47 U.S.C. § 303(y) (2006)).

42. See generally Administrative Procedure Act, Pub. L. No. 79-404, 60 Stat. 237 (codified as amended in scattered versions of 5 U.S.C.).

43. For example, pursuant to the 1993 Budget Act, the FCC a reserve of 57 MHz of spectrum transferred from the federal government at 1390–1395 MHz, 1427–1429 MHz, 1670–1675 MHz and 1710–1755 MHz until after March 22, 2006. See *In re Plan for Reallocated Spectrum*, 11 FCC Rcd. 17841, ¶¶ 4, 64–65 (1996).

44. See *Pleading Cycle Established for Comments and Reply Comments on Petition for Rule Making File by Intelligent Transportation Society of America*, 12 FCC Rcd. 6766 (1997) (stating that ITS America's Petition for Rulemaking was filed on May 19, 1997).

45. *In re Amendment of Parts 2 and 90 of the Commission's Rules to Allocate the 5.850–5.925 GHz Band to the Mobile Service for Dedicated Short-Range Communications of Intelligent Transportation Services*, FCC Docket No.

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operational rules did not conclude until 2006.<sup>46</sup> To date, the DSRC service has seen only limited, mostly experimental or demonstration deployment.<sup>47</sup>

Given the current state of autonomous vehicle technology, it is unclear that there is a current need for a new spectrum allocation for autonomous vehicles. Nonetheless, should such a need arise as the technology matures and are introduced into commercial markets, proponents of such an allocation must consider the often lengthy, contentious, and costly allocation process in their planning.

The development of the commercial cellular service provides a valuable measure of the regulatory hurdles and the extended timeline involved with introducing a new wireless service.<sup>48</sup> The FCC first initiated a rulemaking procedure in 1968, seeking to establish a “truly efficient high capacity” mobile telephone service.<sup>49</sup> The first commercial cellular service did not begin until years later when, in 1984, the FCC first began issuing geographic licensees for metropolitan areas; actual service did not reach rural areas until 1989.<sup>50</sup>

The pursuit of a new spectrum allocation requires a commitment of considerable resources—money, time and technical. Even where an allocation has the requisite support, the outcome is still uncertain given the competing demands for additional spectrum from diverse stakeholders.

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99-305 (1999). FCC action on the petition also resulted from Congressional direction written into statute. See Transportation Equity Act for the 21st Century, Pub. L. No. 105-178, § 5206(f) (1998).

46. See, e.g., *In re* Amendment of the Commission’s Rules Regarding Dedicated Short-Range Communications Services in the 5.850–5.925 GHz Band (5.9 GHz Band), FCC Docket No. 02-302 (2002) [hereinafter Dedicated Short-Range Communications Services]; *In re* Amendment of the Commission’s Rules Regarding Dedicated Short-Range Communications Services in the 5.850–5.925 GHz Band (5.9 GHz Band) [hereinafter Dedicated Short-Range Communications Services], FCC Docket No. 03-324 (2004); *In re* Amendment of the Commission’s Rules Regarding Dedicated Short-Range Communications Services in the 5.850–5.925 GHz Band (5.9 GHz Band), FCC Docket No. 06-110 (2006).

47. See *supra* note 24.

48. Thomas W. Hazlett, *Is Federal Preemption Efficient in Cellular Phone Regulation?*, 56 FED. COMM. L.J. 155, 160–61 (2003).

49. John W. Berresford, *The Impact of Law and Regulation on Technology: The Case History of Cellular Radio*, 44 BUS. LAW 721, 724 (1989).

50. Hazlett, *supra* note 48.

*i. Spectrum Hierarchy*

When allocating a spectrum band to a new service, or introducing a new service into a spectrum band already occupied, the FCC will establish a framework of rights for the various categories of licensees and services that may be in the band. This framework of rights potentially may involve services that exist on a primary, co-primary or secondary basis. Alternatively, the FCC may permit the introduction and use of unlicensed devices in the band. A wireless service that is granted primary status has a higher status and priority right to the spectrum band than licensees that hold secondary status or unlicensed services. The FCC may grant different services primary status in the same band, creating co-primary services. In these instances, licensees in the co-primary services must not cause interference to one another. FCC rules for resolving interference between two licensees that are lawfully operating in accordance with the terms of their licenses are not well-defined (and it is not always the “first in time” that may hold priority in such circumstances) and it is especially important that licensees clearly understand their rights and obligations.

Secondary services typically are not permitted to cause interference to primary services and must accept any interference from primary services. This is true even where a primary status licensee begins operations after a secondary status licensee is already operating; the secondary licensee must accept any interference from the new primary status licensee, assuming it is operating in accordance with its applicable technical rules. However, there have been instances where unlicensed services have been able to claim, in effect, a higher level of effective protection from interference. For example, as further discussed below, unlicensed GPS devices in the 1.5 GHz band have successfully claimed interference protection from proposed adjacent band operations by LightSquared, which holds primary status in the 1525–1559 MHz band. Licensees must carefully consider the implications to them, both of accepting a status in the spectrum hierarchy lower than other existing uses and of the potential for changes and additions to those allocations, to accommodate the introduction of a new service in the band. For example, the FCC in 1997 allocated 300 MHz in the 31 GHz band to the new Local Multipoint

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Distribution Service (LMDS), a wireless broad service originally designed for digital television.<sup>51</sup> Prior to the reallocation, all the incumbent licensees, including governmental entities, such as those operating traffic control systems, were licensed under rules that required they share the frequency on a co-equal, non-protected basis, without protection from harmful interference.<sup>52</sup> Of the 300 MHz allocated to LMDS, incumbent operations in the upper and lower 75 MHz spectrum bands were provided protection from harmful interference LMDS to enable them to continue existing operate.<sup>53</sup> However, with respect to the middle 150 MHz spectrum band, the FCC declined to grant any incumbent licensees protection from harmful interference and accorded them secondary status to LMDS.<sup>54</sup>

For the Nevada Department of Transportation (Nevada DOT), one of the incumbent governmental licensees in the middle 150 MHz spectrum band being reallocated, the Nevada DOT asserted that the FCC's regulatory change resulted in "stranded public investment" of some \$600,000 for equipment that had already been purchased and deployed but was still subject to FCC authorization.<sup>55</sup> In addition, according to the Nevada DOT, the Las Vegas Valley Traffic Operational System, another incumbent governmental licensee in the middle 150 MHz spectrum band with a pending license application, "is now delayed for an indeterminate length of time because of the inability to access the 31 GHz spectrum."<sup>56</sup> The licensees requested, and the FCC ultimately granted, temporary authorizations to operate their systems on a secondary basis until LMDS systems were

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51. Petitions for Reconsideration of the Denial of Applications for Waiver of the Commission's Common Carrier Point-to-Point Microwave Radio Service Rules, *In re* Rulemaking to Amendment Parts 1, 2, 21, and 25 of the Commission's Rules to Redesignate the 27.5–29.5 GHz Frequency Band, To Reallocate the 29.5–30.0 GHz Frequency Band, To Establish Rules and Policies for Local Multipoint Distribution Service and for Fixed Satellite Services (*LMDS Second Report and Order*), 12 FCC Rcd. 12545 (1997).

52. *Id.* ¶ 64.

53. *Id.* ¶ 80.

54. *Id.* ¶¶ 80, 90.

55. See Letter from Roger Grable, Assistant Director - Administration, Nevada Department of Transportation, to William F. Caton, Acting Secretary, FCC Docket No. 92-297, at 1 & n.2 (1997).

56. *Id.* at 1.

deployed in the Las Vegas area.<sup>57</sup>

This example highlights the fact that a service's status in the spectrum hierarchy in a band is not necessarily fixed. Incumbent licensees may find that their status may be changed to accommodate new entrants. As a result, incumbent licensees may incur significant costs—in time and money—to defend their status but may ultimately have to accommodate the new service or move to a new frequency band altogether.

*ii. Band Sharing Issues*

As the competition for spectrum intensifies, and spectrum bands become more congested, band-sharing issues—both within the same band as well as between adjacent bands—will require greater attention. Interference issues may arise not only between licensees operating in the same band, but can also occur between licensees in adjacent bands. Two examples discussed below highlight the need for spectrum users to fully understand the radiofrequency environment in which they plan to operate, including in adjacent bands.

*a. In-Band Sharing: DSRC/FSS Spectrum Sharing Protocol*

DSRC is co-primary with Fixed Satellite Service (FSS) licenses in the 5.9 GHz Band. FSS has approximately 120 earth station sites operating in the 5.9 GHz Band (called the “extended C-band” by FSS), and is used generally for commercial services, such as video uplink for international television transmissions. Immediately adjacent to the 5.9 GHz Band, at 5.925–6.425 GHz, is the satellite “C-band,” which has long been used extensively by commercial FSS operators.

In 1999, when the FCC allocated the 5.9 GHz Band to DSRC, it concluded that DSRC operations should be compatible with FSS operations because FSS earth stations

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57. *Id.* at 2; *In re* Rulemaking to Amend Parts 1, 2, 21, and 25 of the Commission's Rules to Redesignate the 27.5–29.5 GHz Frequency Band, To Reallocate the 29.5–30.0 GHz Frequency Band, To Establish Rules and Policies for Local Multipoint Distribution Service and for Fixed Satellite Services, 13 FCC Rcd. 4856, App. C IV (1998).

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typically use highly directional antennas pointed toward the geostationary orbital arc while DSRC operations will use highly directional antennas pointed toward a highway and operate at relatively low power.<sup>58</sup> While the FCC noted that there might be some areas near an FSS earth station that DSRC systems should avoid, spectrum sharing is possible because of the limited number of FSS earth stations and their use of highly directional antennas.<sup>59</sup>

Subsequent to the FCC's decision to allocate the 5.9 GHz band to DSRC on a co-primary basis with FSS operations, the FSS industry raised concerns regarding the potential for interference between the two services, both in the 5.9 GHz band, but also from FSS operations in the immediately adjacent satellite "C" band.<sup>60</sup> The FSS industry suggested that there be prior coordination between DSRC and FSS for locating DSRC facilities, and such prior coordination could take into account the "noise floor"—that is, the level of RF energy—present from FSS operations in both the 5.9 GHz band and immediately adjacent satellite "C" band.<sup>61</sup> However, at the urging of both the DSRC and FSS industry groups, the FCC declined to adopt any of these, or other, suggestions so that the two industry groups could develop an agreed-upon "spectrum sharing protocol."<sup>62</sup>

In February 2008, the DSRC and FSS industry groups submitted to the FCC the results of these discussions: the DSRC/FSS Earth Station Spectrum Sharing Protocol (Spectrum Sharing Protocol)<sup>63</sup> that calls for a minimum level of prior coordination between in-band DSRC and FSS

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58. DSRC Spectrum Allocation Order, *supra* note 22, ¶ 1.5.

59. *Id.*

60. Petition for PanAmSat Corporation for Reconsideration or Clarification, *In re* Amendment of Parts 2 and 90 of the Commission's Rules to Allocate the 5.850–5.925 GHz Band to the Mobile Service for Dedicated Short-range Communications of Intelligent Transportation Services, ET Docket No. 98-95 (filed Dec. 79, 1999).

61. *Id.*; see DSRC Rules Order, *supra* note 21, ¶¶ 77–78.

62. DSRC Rules Order, *supra* note 21, ¶¶ 79–80.

63. Mintz Levin P.C., *Written Ex Parte in WT Docket No. 01-90 and ET Docket No. 98-95: DSRC/FSS Earth Station Spectrum Sharing Protocol* (Feb. 18, 2008) [hereinafter: *DSRC/FSS Earth Station Spectrum Sharing Protocol*, available at [https://mail-attachment.googleusercontent.com/attachment/u/0/?ui=2&ik=d10ea2544d&view=att&th=137574ba22d5ae87&attid=0.2&disp=inline&realattid=f\\_h2atzsox2&safe=1&zw&saduie=AG9B\\_P8cEVYKWixoXIcU71jp-tfr&sadet=1337201295101&sads=pvaSCpCvIk8BOltXLluTDtqkEVM](https://mail-attachment.googleusercontent.com/attachment/u/0/?ui=2&ik=d10ea2544d&view=att&th=137574ba22d5ae87&attid=0.2&disp=inline&realattid=f_h2atzsox2&safe=1&zw&saduie=AG9B_P8cEVYKWixoXIcU71jp-tfr&sadet=1337201295101&sads=pvaSCpCvIk8BOltXLluTDtqkEVM)].

operations.<sup>64</sup> The Spectrum Sharing Protocol includes two parts: (1) a “technical approach” that considers how DSRC and FSS systems will operate, establishes the appropriate interference criteria and recommends a method for determining the interference potential in specific cases; and (2) a “procedural approach” that applies the results of the technical approach and identifies the rights and responsibilities of the spectrum sharing parties—both DSRC and FSS—under various conditions.<sup>65</sup> In addition, the Spectrum Sharing Protocol proposes changes to the FCC’s Rules to implement the recommended technical and procedural coordination procedures.<sup>66</sup> To date, the FCC has not taken any action regarding the Spectrum Sharing Protocol.

*b. In-Band Sharing: Unlicensed Operations*

On February 22, 2012, President Obama signed into law the Middle Class Tax Relief and Job Creation Act of 2012 (2012 Tax Act),<sup>67</sup> which, in addition to several tax and job incentive measures, included significant provisions addressing spectrum issues. Included in the 2012 Tax Act is an add-on provision that implicates permitting unlicensed operations in the 5.9 GHz, particularly wireless broadband services, such as Wi-Fi. Section 6406 of the 2012 Tax Act directs the National Telecommunications and Information Administration (NTIA) of the US Department of Commerce to conduct a study evaluating “known and proposed spectrum-sharing technologies” and the potential risks to Federal users in the 5.9 GHz band if unlicensed operations were permitted.<sup>68</sup> NTIA is to conduct and submit the study not later than 18 months after passage of the 2012 Tax Act, by August 22, 2013.<sup>69</sup> From the plain language of the statute,

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64. Notably, the two industry groups were unable to reach a consensus regarding how to address the potential for interference to DSRC operations from FSS in the adjacent satellite “C” band.

65. See *DSRC/FSS Earth Station Spectrum Sharing Protocol*, *supra* note 63, at 2–6.

66. *Id.* at App. A.

67. Middle Class Tax Relief and Job Creation Act of 2012, Pub. L. No. 112-96 (2012), available at <http://www.gpo.gov/fdsys/pkg/PLAW-112publ96/pdf/PLAW-112publ96.pdf>.

68. *Id.* § 6406(b)(1).

69. *Id.* § 6406(b)(2)(B).

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however, it is unclear whether the NTIA study would even consider DSRC operations in the 5.9 GHz band as the study, according to the statute, is to evaluate “the risk to Federal users if unlicensed [use] is permitted.”<sup>70</sup> The DSRC service is not referenced in the statute.

Permitting unlicensed operations in the 5.9 GHz band may raise concerns for DSRC operations in the band. Unlicensed devices typically are permitted without restriction to location and without any form of site registration or other procedure for a third party to identify the operator of the unlicensed facility. Several DSRC applications involve safety-of-life transmissions. Unrestricted and unregistered unlicensed operations could compromise these critical safety applications.

*c. Adjacent-Band Sharing: LightSquared*

LightSquared, and its predecessor entities, has been offering commercial satellite voice and data services since 1996 for asset tracking, maritime and government applications (i.e., disaster relief). LightSquared is authorized to operate in the satellite “L” band, specifically at: 1522–1544 MHz, 1545–1559 MHz, 1626.5–1645.5 MHz, and 1646.5–1660.6 MHz. LightSquared indicated it was planning to deploy a ground-based wireless network in the United States using its same satellite “L” band and to provide wholesale capacity to other wireless service providers.

In its January 2011 Order, the FCC provided conditional authority to LightSquared to build-out its planned terrestrial network subject to LightSquared first satisfying certain conditions.<sup>71</sup> The most significant condition relates to resolving potential interference issues to GPS receivers. The concern was that LightSquared’s proposed terrestrial network, which is to be deployed at frequencies immediately adjacent to GPS at 1.5 GHz, would cause significant harmful interference to GPS devices, potentially rendering the service unusable. The GPS signals from the satellite are relatively weak compared to the proposed strength of the LightSquared

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70. *Id.* § 6406(b)(1).

71. See LightSquared Subsidiary LLC Request for Modification of its Authority for an Ancillary Terrestrial Component, Order and Authorization, DA 11-133, 26 FCC Rcd. 566 (2011).



signals in the adjacent band. The GPS industry expressed its view that the more powerful LightSquared signals would overpower the GPS receivers, causing them to become overloaded or jammed. The FCC required that, as a prior condition of granting authority to deploy and operate the requested terrestrial network, LightSquared identify and resolve the potential interference concerns to GPS. The Commission also required that LightSquared convene a Working Group, composed of representatives from the GPS community (users, device manufacturers, etc.) and government (including the Department of Defense, Department of Transportation and National Telecommunications and Information Administration), to look into the interference concerns.

LightSquared submitted its final report to the FCC on June 30, 2011, acknowledging, first, that its proposed operations in the 10 MHz of its frequencies closest to the GPS operations will “adversely affect the performance of a significant number of GPS receivers.”<sup>72</sup> However, LightSquared claimed that the reason is not based on the fact that it would operate in a manner inconsistent with the FCC’s rules, but because the GPS industry failed, in effect, to properly manufacture devices that can adequately reject transmissions from adjacent band operations.<sup>73</sup> Second, LightSquared argued that its operations in its lowest frequency band, the spectrum furthest away from GPS operations, would not cause interference to the majority of GPS devices. However, further testing sponsored by the U.S. government, reached a different conclusion:

LightSquared’s original and modified plans for its proposed mobile network would cause harmful interference to many GPS receivers . . . . Based upon this testing and analysis, there appear to be no practical

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72. RECOMMENDATION OF LIGHTSQUARED SUBSIDIARY LLC, SAT-MOD-20101118-002394 (June 30, 2011).

73. On March 12 and 13, 2012, the FCC convened a workshop to examine the issue of spectrum efficiency and receiver performance. While the workshop was not directed specifically at the LightSquared situation, it does suggest that the FCC is concerned that certain categories of devices, such as GPS receivers, could be improved to better reject transmissions from adjacent band operations. See *Workshop on Spectrum Efficiency and Receivers (Day 1)*, FCC.GOV (Mar. 12, 2012), <http://www.fcc.gov/events/workshop-spectrum-efficiency-and-receivers-day-1>.

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solutions or mitigations that would permit the LightSquared broadband service, as proposed, to operate in the next few months or years without significantly interfering with GPS.<sup>74</sup>

On February 14, 2012, the National Telecommunications and Information Administration (NTIA) of the U.S. Department of Commerce notified the FCC of the results of further testing conducted by the federal government.<sup>75</sup> NTIA reached two conclusions. First, LightSquared's proposed terrestrial network will negatively impact GPS services and it is not practically possible to mitigate the potential interference problems.<sup>76</sup> Second, while future GPS devices may be able to mitigate the potential interference problems, the time and costs involved to do so do not support LightSquared's planned deployment schedule of its terrestrial network as envisioned in the 1525–1559 MHz band.<sup>77</sup> As a result of the NTIA's letter, the FCC then released a public notice concluding that, based on the results of the NTIA study, the condition precedent to granting commercial authority to LightSquared for its terrestrial network, requiring that the harmful interference concerns be resolved, had not been met and proposed to: (1) vacate its earlier conditional waiver granting authority to operate the proposed terrestrial network; and (2) modify LightSquared's existing license to "suspend indefinitely" its authorization to operate a terrestrial network.<sup>78</sup> The FCC sought public comments on these proposals.<sup>79</sup> As of the date of publication, the FCC has

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74. A. Carter and J. Porcari, Co-Chairs, National Space-Based Positioning, Navigation and Timing (PNT) Executive Committee, Letter to L. Strickling, Assistant Secretary and Administrative, National Telecommunications and Information Administration (Jan. 13, 2012).

75. See Letter from Lawrence E. Strickling, Assistant Secretary for Communications and Information, U.S. Department of Commerce, to Julius Genachowski, Chairman, FCC (Feb. 14, 2012).

76. *Id.* at 1.

77. *Id.*

78. FED. COMM'NS COMM'N, DA 12-214, PUBLIC NOTICE: INTERNATIONAL BUREAU INVITES COMMENT ON NTIA LETTER REGARDING LIGHTSQUARED CONDITIONAL WAIVER (2012).

79. *Id.* at 4. On February 22, 2012, LightSquared announced that it would laying off 45 percent of its 330-employee workforce as a cost savings measure. Svea Herbst-Bayliss, *Lightsquared Plans to Cut 45 Percent of Workforce*, REUTERS (Feb. 21, 2012), <http://www.reuters.com/article/2012/02/21/us-lightsquared-idUSTRE81K1XN20120221>. Subsequently, on May 14, 2012, Lightsquared filed for bankruptcy protection. Tiffany Kary & Michael Bathon,

yet to issue a final decision.

*iii. Considerations for Autonomous Vehicles*

As autonomous vehicles evolve there will no doubt be different architectures and designs developed by competing interests. At this point no one can predict with any level of certainty which, if any, of these designs and systems will be selected by the marketplace. What is clear, however, is that public acceptance of the reliability and safety of autonomous and advanced vehicles will be critical to the market success of any potential architecture. In turn, the RF environment utilized and available for autonomous vehicles will be a key element in ensuring the safety of operations and securing public acceptance. Spectrum is a scarce national resource and an enabling element of much of the growth of the Internet and technology. It is difficult to obtain and sometimes even harder to retain. Developers of autonomous and advanced vehicles must consider these issues as they plan for roll out and growth.

Some initial deployment scenarios for autonomous vehicles envision that early operation will occur on closed or limited access highways, dedicated lanes or closed campus. In this scenario, autonomous vehicles would expect to be registered or otherwise authorized to access the dedicated infrastructure. Under this type of more rigorous, centralized command structure, the operator of the dedicated infrastructure would also be able to control the spectrum environment for users, which would make it easier to enable a shared-spectrum environment. Answering these questions will likely turn on a consideration of the critical safety-related applications—such as vehicle collision avoidance systems—that are expected to utilize spectrum resources. Given the nature of such transmissions, autonomous vehicles will need access to sufficient and reliable spectrum resources to support these applications; that is, access to enough RF capacity to support the application(s) in question, as well as access without significant delay—from a technical perspective—and that is not at risk from a level of harmful interference that

might cause the application to fail.

### *B. Assignment*

Once a spectrum band has been allocated to a new service, the next step is for the FCC to assign rights (a “license”) to the band or specific frequencies within a band to individual entities (or “licensee”). Historically, licenses have been issued in several ways: on a first-come, first-serve basis; on a shared, “non-exclusive” basis, after review and approval by an FCC-certified frequency coordinator or band manager; on an “exclusive” basis in a defined geographic area; on an unlicensed basis; or on the basis of licensing by rule. A discussion of these mechanisms follows. Also examined are related issues of creating a service definition and licensee eligibility, both of which impact the assignment of licenses to specific users.

#### *1. Auctions*

Congress first authorized the FCC to award spectrum rights in a band through auctions in the Omnibus Budget Reconciliations Act of 1993.<sup>80</sup> Prior to 1993, spectrum rights had been generally awarded on a first-come, first-serve basis, unless more than one applicant applied for the same license (termed, “mutual exclusivity”).<sup>81</sup> In cases of mutual exclusivity, the FCC used comparative hearings or random selection to determine which applicant best satisfied the “public interest, convenience and necessity” standard. Comparative hearings, a quasi-judicial proceeding, were both expensive and time consuming. In response to the huge demand for the first commercial cellular licenses, in 1981, Congress authorized the FCC to award spectrum licenses by lottery. However, this process also proved imperfect and resulted in a host of speculative applicants and a secondary market for the licenses that delayed the build-out of the networks and service to the public.

The Omnibus Budget Reconciliation Act of 1993 authorized the FCC for the first time to award licenses by

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80. Omnibus Budget Reconciliations Act of 1993, Pub. L. No. 103-66, § 6002, 107 Stat. 312, 387–392 (codified as amended at 47 U.S.C. § 309(j) (2006)).

81. *See generally* The FCC Report to Congress on Spectrum Auctions, 13 FCC Rcd. 9601 (1997).

auction where one or more applicants sought the same license (i.e., mutual exclusivity). Auctions were believed to provide significant advantages over either comparative hearings or lotteries: dissuasion of applicants from speculating in the licenses, providing a new source of revenue to the federal government, and resulting in service being implemented more quickly because the auction winners would want to see a timely return on their investment. Congress did not mandate any particular form of auctions, but instead directed the FCC to examine differing methodologies designed to protect the public interest and promote certain public policy goals. Congress also directed that auction revenues must be paid into the U.S. Treasury, rather than any other separate account maintained by the FCC or other federal governmental entities.

Since the first auction in 1994 for narrowband PCS licenses, through the most recent auction in July 2011 for licenses in the 700 MHz band, the Commission has conducted over eighty spectrum license auctions. According to CTIA (the U.S. cellular industry trade association), FCC-sponsored auctions have resulted in over fifty-two billion dollars in revenues deposited in the U.S. Treasury through 2010.<sup>82</sup>

The newest form of auction is the so-called “voluntary incentive” auctions. According to the FCC, a voluntary incentive auction is a voluntary, market-based mechanism to compensate existing licensees for returning their spectrum to make it available for other new uses, such as mobile broadband services.<sup>83</sup> Most recently, Congress provided authority to the FCC to use incentive auctions for the first time.<sup>84</sup> The same legislation specifically contemplates using incentive auctions for spectrum to be released by the television broadcasters (so-called “white spaces”) as a result of their transition to digital operations.<sup>85</sup>

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82. CTIA the Wireless Association, CTIA.ORG, <http://www.ctia.org> (last visited May 14, 2012).

83. *Incentive Auctions*, *supra* note 40.

84. Middle Class Tax Relief and Job Creation Act of 2012, Pub. L. No. 112-96, § 6402 (2012), available at <http://www.gpo.gov/fdsys/pkg/PLAW-112publ96/pdf/PLAW-112publ96.pdf> (adding new subsection 47 U.S.C. § 309(j)(8)(G)).

85. *Id.* § 6403.

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The FCC has used spectrum auctions to make available licensees for commercial wireless services, which are in a position to recoup the costs to acquire the spectrum licensees by charging customers for the wireless service. The Balanced Budget Act of 1997 specifically exempted public safety radio services from auctions.<sup>86</sup> In addition, the FCC may not use auctions to award licenses issued on a non-exclusive basis where, for example, licensees are able to share access to a spectrum band through mechanisms such as frequency coordination or other spectrum management techniques that avoids creating mutual exclusivity.<sup>87</sup>

## 2. *Licensing*

There are several different licensing mechanisms that the FCC may use to assign licensees for a particular service in a spectrum band: site-specific, geographic, national, licensing-by-rule, and unlicensed. When considering a particular licensing method, the FCC considers several factors: promotion of new communications services, spectrum management, coordination and efficiency, and administrative burdens and costs.

### *i. Site-Specific Licensing*

Under the site-specific licensing process, applications seek authorization to operate at certain frequencies at an identified location. There are two types of site-specific licensing: shared and exclusive. For shared site-specific licensing, licensees are assigned licenses to operate at a specific location on a specific frequency or frequencies.<sup>88</sup> Licenses are assigned on first-come, first-serve basis. The proposed frequency or frequencies and location(s) must also be reviewed and approved by an FCC-certified frequency coordinator.<sup>89</sup> The frequency coordinator ensures that the applicant's proposed operations would not cause harmful interference to existing licensees, such as by assigning

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86. Balanced Budget Act of 1997, Pub. L. No. 105-33, § 3002, 111 Stat. 251 (1997) (amending 47 U.S.C. § 309(j) (2006)).

87. *Id.* § 309(j)(6)(D).

88. *In re* Amendment of the Commission's Rules Regarding Dedicated Short-Range Communication Services in the 5.850–5.925 GHz Band (5.9 GHz Band) [hereinafter DSRC NPRM], 17 FCC Rcd. 23136, ¶ 41 (2002).

89. 47 C.F.R. § 90.175 (2010).

different channels within the band to different licensees, or by imposing technical limitations. The applicant files its license application via the FCC's licensing database, indicating the proposed frequency or frequencies, geographical coordinates, and other technical information regarding the proposed station. Site-specific licensing, however, is seen as administratively cumbersome and costly for licensees that may, for example, have of hundreds of specific sites.<sup>90</sup> In addition, licensees are unable to relocate transmitters without seeking prior FCC approval.<sup>91</sup>

Exclusive site-specific licensing under the FCC's Rules generally does not require the involvement of a frequency coordinator. Instead, exclusive licenses are issued by the FCC and receive protection from co-channel operations based on geographic separation requirements, or other technical parameters, established by the FCC. However, with the introduction of auctions in 1994 as a means to resolve mutual exclusivity between licensees, the FCC has not used exclusive site-specific licensing since 1993.

*ii. Geographic Area Licensing*

Typically, geographic area licensing is used to assign licenses for commercial wireless services. Under this licensing procedure, licensees are granted authority to locate their transmitters and operate in defined geographic areas.<sup>92</sup> An advantage of geographic area licensing is that a licensee is provided flexibility to move, modify, or add to its operations, within the authorized geographic area of operation, without prior FCC approval, thus lessening the administrative burdens and costs associated for a licensee.<sup>93</sup> The FCC has also found that geographic area licensing fosters economies of scale that results in lower equipment and service costs.

Commercial wireless services, such as cellular and PCS, are licensed using geographic area licensing. Licensees for these services are assigned exclusive rights to identified frequencies for operation within specified geographic areas, called, for example, "Major Trading Areas," "Basic Trading

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90. DSRC NPRM, *supra* note 88, ¶ 46.

91. *Id.*

92. *Id.* ¶ 47.

93. *Id.*

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Areas,” and the like. Because of the mutual exclusivity inherent in this type of geographic area licensing, commercial wireless licensees have been awarded through auction.

In 2003, the FCC first used geographic area licensing for public safety services, but without any exclusivity elements. The FCC designated the 4.9 GHz Band (4.940-4.990 GHz) in 2002 for public safety use upon transfer from federal government use and specified, for the first time, that the licenses would be awarded on a geographic area basis consistent with a licensee’s legal/political jurisdictional area of operations (state, county, city, etc.).<sup>94</sup> The FCC provided that all frequencies are to be shared among licensees. Adjacent, co-located and overlapping licensees must cooperate and coordinate their spectrum use.<sup>95</sup> Moreover, shared frequency use and coordination are to be enabled by sharing arrangements between and among licensees, frequency utilization procedures, low power transmitter limits, and the nature of public safety operations in general, thereby permitting all licensees to use the full 50 MHz in the band.<sup>96</sup>

Subsequently in 2003, the FCC adopted the technical and service rules for the DSRC band at 5.9 GHz.<sup>97</sup> Using a combination of site-specific and geographic area licensing, the FCC’s rules establish a two-step licensing structure for the fixed DSRC roadside units (RSUs), which seeks to maximize efficiency and minimize the administrative burden on licensees. First, licensees, public, public safety, and private and commercial entities, are to be granted non-exclusive licenses for identified geographic areas, including nationally, for the entirety of the band.<sup>98</sup> Second, once a license has been granted, licensees must then register their individual RSUs at specific, identified locations (along with certain technical and operational information) in the FCC’s licensing database.<sup>99</sup> RSU site authorization occurs upon successful

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94. *See In re the 4.9 GHz Band Transferred from Federal Government Use*, 18 FCC Rcd. 9152 (2003) [hereinafter 4.9 GHz Band Order].

95. *Id.* ¶ 27. *See also* 47 C.F.R. § 90.137(b) (2010) (requiring that licensees and users cooperate with one another in the selection and use of frequencies so as to reduce interference and maximize spectrum usage).

96. 4.9 GHz Band Order, *supra* note 94, ¶ 28.

97. *See* DSRC Rules Order, *supra* note 21.

98. *Id.* ¶ 57.

99. *Id.* ¶ 59.



registration in the database.

*iii. Corridor Licensing*

A subset of geographic licensing is “corridor licensing,” where the authorized geographic area is a defined “corridor” encompassing a natural or man-made landmark, rather than by state lines, city/county borders, census information, and/or economic data.<sup>100</sup> For example, in 2003, the FCC approved a joint venture between AT&T Wireless Services, Inc. and Cingular Wireless LLC to build the necessary infrastructure along approximately 4000 miles of rural highways to provide commercial wireless services for travelers on these roads and in adjacent areas.<sup>101</sup> The DSRC licensing process also enables corridor licensing. A state transportation agency or thruway authority could license its RSU facilities along a highway, thruway, major bridge, or tunnel.

*iv. Licensing By Rule*

Current law permits the FCC to implement “licensing by rule” for the operation of stations in certain radio services as identified in statute, such as citizens band radio service.<sup>102</sup> Under the license-by-rule methodology, the FCC does not issue individual licenses and there is no frequency coordination required. The FCC views licensing by rule as the most appropriate licensing mechanism for lower power, short-distance services with multiple, shared channels.<sup>103</sup> For certain services, it is impractical for the FCC to issue individual station licenses where there may be thousands, or more, deployed radio devices that are not associated with a specific, fixed station.<sup>104</sup>

For example, in 2000, the FCC concluded that the then-proposed wireless medical telemetry services could be defined

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100. See *FCC Areas*, FCC.GOV, <http://transition.fcc.gov/oet/info/maps/areas/> (last visited May 14, 2012) (describing sources for FCC’s establishment of geographic area licensing designations “Cellular Market Areas,” “Basic Trading Areas,” “Major Trading Areas,” “Regional PCS Areas,” among others).

101. Wireless Telecommunications Bureau Grants Consent for the Full and Partial Assignment and Transfer of Control of Licenses to Implement GSM Corridor LLC Joint Venture, 18 FCC Rcd. 1845 (2003).

102. 47 U.S.C. § 307(e) (2010).

103. DSRC Rules Order, *supra* note 21, ¶ 54.

104. *Id.*

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as a citizens band radio service under the authorizing statute, thus enabling the FCC to apply licensing by rule.<sup>105</sup> Subsequently, in 2004, the FCC again applied an expansive definition of the citizens band radio service to encompass the vehicle “on-board” radio devices in the DSRC service.<sup>106</sup> The FCC concluded that authorizing the DSRC on-board radio devices via licensing by rule is appropriate because the DSRC band will be shared by millions of motorists and there is no mutual exclusivity among users.<sup>107</sup> Further, the FCC found that licensing by rule would minimize the regulatory procedures for these devices, thus facilitating deployment.<sup>108</sup>

*v. Unlicensed Use*

As described above, certain wireless devices are permitted to operate in a particular band on an “unlicensed” basis. Wi-Fi is the most common type of unlicensed devices. Covered devices need not obtain an individual license to operate, but must satisfy the relevant technical requirements in Part 15 of the FCC’s Rules,<sup>109</sup> which also include “radiated emission limits” for covered devices to minimize the potential for unlicensed devices to cause interference to licensed radio services.<sup>110</sup> In addition, most devices that intentionally emit radiofrequency radiation (that is, transmit radio signals as their primary function) must receive FCC equipment certification before they can be marketed, sold, and deployed.<sup>111</sup>

For the DSRC service, the FCC considered whether to authorize vehicle on-board radio units as unlicensed devices under Part 15. The FCC rejected authorizing these devices as unlicensed devices, choosing instead to apply licensing by rule because it concluded that the Part 15 rules would not provide sufficient protection from interference to the safety-of-life and public safety services and, as a result, thwart deployment of

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105. *In re* Amendment of Parts 2 and 95 of the Commission’s Rules to Create a Wireless Medical Telemetry Service, 15 FCC Rcd. 11206 (2000).

106. DSRC Rules Order, *supra* note 21, ¶ 67.

107. *Id.*

108. *Id.*

109. 47 C.F.R. §§ 15.1–15.615 (2010).

110. DSRC Rules Order, *supra* note 21, ¶ 53.

111. *Id.*

DSRC services.<sup>112</sup> Elsewhere in the same order, the FCC included the requirement that all DSRC radio devices—whether associated with fixed stations or as vehicle on-board equipment—be certified, because of their expected wide deployment (potentially in millions of vehicles) and non-compliance with technical and emission limits could cause “serious interference problems.”<sup>113</sup>

*vi. Considerations for Autonomous Vehicles.*

As the road tests conducted by Google demonstrate, autonomous vehicles are being developed to access all manner of highway, secondary, and local roads throughout the United States, without limitation and essentially their access is no different than that of today’s “regular” vehicles; any spectrum licensing scheme adopted for autonomous vehicles must reflect this fact. A further question is whether there will be any form of supporting infrastructure for autonomous vehicles. If, however, deployment occurs in limited access environments, such as on a dedicated highway, reserved lanes, or on a closed campus, some form of a geographic license would seem applicable. Where such a licensee utilizes specific infrastructure sites to transmit messages to the autonomous vehicles, it would also seem advantageous to identify those sites through a form of registration or similar mechanism.

A second licensing issue concerns ensuring the minimum burden on the vehicle operators. Individual drivers that purchase and “operate” autonomous vehicles should not be expected to obtain an FCC license; indeed, there could eventually be millions of these vehicles, potentially rendering any licensing process burdensome and impractical. If it is assumed, however, that autonomous vehicles will be deployed with radio devices, there needs to be some form of licensing for this equipment, even if individual drivers are not required to obtain an FCC license.

There are two options for licensing the on-board vehicle radio devices: unlicensed or licensing by rule. Both options would seem to be able to support the widespread deployment of multiple, perhaps millions, of radio devices installed in

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112. *Id.* ¶¶ 65, 67.

113. *Id.* ¶ 44.

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vehicles. Again, the DSRC experience offers some guidance for autonomous vehicles. The FCC rejected unlicensed operation for DSRC because the applicable technical rules would not provide sufficient protection from interference to safety-of-life and public safety services.<sup>114</sup> Autonomous vehicles will likely transmit similar safety-of-life messages that need protection from interference. Instead, the FCC adopted licensing by rule for on-board DSRC radio devices because: (1) the band would be shared by millions of motorists; (2) there is no mutual exclusivity among users, and (3) the licensing procedures minimize the regulatory burden, thus facilitating deployment.<sup>115</sup> The same considerations exist for autonomous vehicles.

Licensing by rule also provides an additional benefit. Given the complex technology behind autonomous vehicles, it is likely that the technology will be developed and deployed only by the vehicle OEM or its suppliers. Even where a third-party develops and deploys the technology, such as Google, the technology will need to be installed on the vehicle by technical experts. It seems unlikely that an individual driver would buy an aftermarket autonomous vehicle “aftermarket add-on” and equip a vehicle by him or herself, which is more similar to installing an unlicensed device. The vehicle OEM, supplier, or “sophisticated” third-party developer would be in the best position to obtain FCC approval of the on-board radio devices and ensure that they are installed and operating as intended and consistent with the FCC’s rules.<sup>116</sup> Authorization of these devices as unlicensed devices does not provide the same technical and regulatory controls that are necessary to support autonomous vehicles. As was the case for DSRC, licensing by rule appears to be the more appropriate option for autonomous vehicles.

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114. *Id.* ¶¶ 65, 67.

115. *Id.* ¶ 67.

116. Under this scenario, it would also appear possible for the vehicle OEM, or even a third-party developer, to maintain a database of deployed vehicles and their user/owners. If a problem with the technology is found after deployment, the user/owner could be notified to return the vehicle for updated or repair. Such a mechanism does not seem substantially different than existing recall programs managed by the vehicle OEMs and administered by the National Highway Traffic Safety Administration. See *Recalls & Defects*, NHTSA, <http://www.nhtsa.gov/Vehicle+Safety/Recalls+&+Defects> (last visited May 24, 2012).

### 3. *Service Definition*

The service definition establishes several key elements of the service: its intended purpose, the expected benefits, type of messages to be transmitted (i.e., voice or data, or both), as well the nature of the service itself, such as for public safety or commercial purposes. It is important that the service definition be accurate and complete. A definition that is too vague could open the door to inconsistent users or if, in the alternative, drafted too narrowly, leave legitimate users out in the cold. The service definition for DSRC adopted by the FCC is instructive.

The use of radio techniques to transfer data over short distances between roadside and mobile radio units, between mobile units, and between portable and mobile units to perform operations related to the improvement of traffic flow, traffic safety, and other intelligent transportation service applications in a variety of environments. DSRC systems may also transmit status and instructional messages related to the units involved.<sup>117</sup>

In order to promote flexible use of the 5.9 GHz band, the FCC decided not to limit the definition to “non-voice” transmissions (that is, only data transmissions) and to permit the service to operate in a “variety of environments” without limitation (i.e., only in “private” or “commercial” environments).<sup>118</sup> Moreover, the FCC refused to exclude the possibility of using the band in the future for a commercial wireless service.<sup>119</sup>

### 4. *Licensee Eligibility*

Under the FCC’s current rules, licensee eligibility to operate in a particular band is determined primarily by the characteristics of the entity at issue rather than the nature of the transmissions it uses. For example, the FCC has created a “Public Safety Pool” of frequency bands that are available to identified “classes” of public safety entities.<sup>120</sup> Complicating

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117. 47 C.F.R. § 90.371 (2010).

118. DSRC Rules Order, *supra* note 21, ¶¶ 46–49.

119. *Id.* ¶ 48.

120. 47 C.F.R. § 90.20(a) (stating that identified public safety classes include police, fire, highway maintenance, forestry-conservation, local governments, emergency and other medical services, rescue organizations, disabled persons, veterinarians, school buses and beach patrols).

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matters is that there are several differing definitions of “public safety services” that are not consistent in identifying classes or types of eligible entities. The definition of “public safety services” in section 337(f)(1) of the 1934 Communications Act is read to limit eligibility to so-called “traditional” public safety entities: police, fire, and medical.<sup>121</sup> Alternatively, section 309(j)(2) provides an exemption from auction for spectrum to be licensed to public safety entities. This exemption is seen as reaching traditional (police, fire, emergency medical) public safety entities, as well as “non-traditional” public safety entities, such as utilities, railroads, transit system, pipelines, private ambulances, and volunteer fire departments.<sup>122</sup> This example illustrates the need for careful definition of eligibility requirements to ensure that the intended categories of users will be able to apply for, and be granted licenses.

### *C. Spectrum Management, Interference Mitigation and Resolution*

The FCC’s Rules for all wireless services are designed primarily to ensure that the potential for interference between licensees and services is minimized. To this end, the FCC has established several concepts and mechanisms for managing access to spectrum and interference mitigation and resolution.

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121. 47 U.S.C. § 337(f)(1) (2006);

The term “public safety services” means services – (A) the sole or principal purpose of which is to protect the safety of life, health, or property; (B) that are provided – (i) by State or local government entities; or (ii) by nongovernmental organizations that are authorized by a governmental entity whose primary mission is the provision of such services; and (C) that are not made commercially available to the public by a provider.

*Id.*

122. 47 U.S.C. § 309(j)(2) (2006);

The exemption from spectrum auction shall apply to licenses (A) for public safety services, including private internal radio services, used by State and local governments and non-government entities and including emergency road services provided by not-for-profit organizations, that (i) are used to protect the safety of life-, health or property; and (ii) are not made commercially available to the public.

*Id.* The accompanying House-Senate Conference Report specifically noted that the definition of public safety services found in Section 309(j)(2) is “much broader” than the explicit definition of “public safety services” found in Section 337(f)(1). H.R. Conf. Rep. No. 105-217, 105th Cong. Sess., at 572 (1997).

### 1. *Spectrum Management*

There are several differing processes and types of entities for managing access spectrum by potential licensees, including certified and non-certified frequency coordinators, commercial coordination services, the FCC's rules, automated software, and the FCC's licensing database.

#### i. *Certified Frequency Coordinators*

Starting in the 1980s, the FCC began certifying outside organizations to analyze and recommend the most appropriate frequencies for license applicants for public safety services and certain private wireless services authorized under part 90 of the FCC's Rules.<sup>123</sup> FCC-certified frequency coordinators first act as an eligibility "filter" to determine whether the applicant qualifies as a licensee for a particular service. The coordinator can refuse to forward an application to the FCC if the applicant is deemed unqualified. If an applicant meets the eligibility requirements, the coordinator will identify and recommend to the FCC the appropriate frequency or frequencies for the applicant. An applicant must provide a coordinator with proposed site coordinates and any necessary technical parameters (i.e., antenna height, output power, emissions, etc.) to enable the coordinator to conduct its analysis. A coordinator's "showing" of coordination and recommended frequency or frequencies are then provided to the FCC for the purposes of granting the license.

#### ii. *Non-Certified Frequency Coordinators*

Private, non-FCC-certified frequency coordinators provide similar services to fixed microwave service<sup>124</sup> applicants and fixed satellite services (FSS)<sup>125</sup> applicants. As a condition of their licenses, applicants in both services must present evidence to the FCC that a proposed station has been coordinated with incumbent licensees within their bands, including incumbents of the other service.<sup>126</sup> Unlike the FCC-certified frequency coordinators, the private coordinators do

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123. 47 C.F.R. § 90.

124. *Id.* § 101.

125. *Id.* § 25.

126. *Id.* § 25.203 (FSS), § 101.103 (fixed microwave).

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not also serve as eligibility filters of an applicant's qualifications to hold a license in either service; they have no authority to review and judge an applicant's fitness to be a licensee. The FCC determines a licensee's qualifications when it reviews the license application.

*iii. Commercial Coordination Services*

Existing apart from FCC-recognized coordinators, there are also private, commercial coordination services that have developed to meet specific needs of the wireless industry to assist with frequency planning, conducting field studies and analysis for siting wireless facilities, and maintaining comprehensive databases of current licensing information regarding various wireless and satellite services.<sup>127</sup> These entities exist outside of the formal FCC's frequency coordination process.

*iv. FCC Rules and Licensing Databases*

The FCC's rules themselves may specify coordination procedures. For example, as noted above, fixed microwave service and FSS licensees must coordinate with incumbent licensees in the other services prior to deploying in their shared bands. The FCC's rules set forth the types of technical information that must be provided by a license applicant to incumbent licensees including analyses of potential interference, as well as any proposed physical steps (such as shielding) to protect the incumbent from potential interference.<sup>128</sup> The FCC also maintains several publicly-available licensing databases that an applicant can review to identify potential frequencies or conflicts with incumbent licensees.<sup>129</sup>

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127. See generally *Welcome*, COMSEARCH.COM, <http://www.comsearch.com> (last visited May 14, 2012).

128. See, e.g., *Id.* § 25.203(b)–(c).

129. E.g., *Universal Licensing System*, *supra* note 24 (discussing that DSRC licensees are to be entered into the FCC's "Universal Licensing System"); *My IBFS*, FCC.GOV, <http://licensing.fcc.gov/myibfs/> (last visited May 14, 2012) (displaying a licensing database for satellite services); *OET Experimental Licensing System*, FCC.GOV, <https://apps.fcc.gov/oetcf/els/index.cfm> (last visited May 14, 2012) (displaying a licensing database for experimental licenses).



*v. Message Prioritization*

Yet another mechanism for spectrum management is to structure the band to provide prioritization to certain types of messages over others. In other words, where a message with a higher priority is transmitting, a message with a lower priority would have to wait until the higher-priority message is concluded before it is transmitted, or the lower priority message would be interrupted to permit the higher-priority message to go through. The FCC created such a message prioritization framework for the DSRC service. The FCC provided that “safety-of-life” messages, such as vehicle-to-vehicle collision avoidance, have “access priority” over all other DSRC communications.<sup>130</sup> Next, “public safety” communications have access priority over all DSRC communications except safety-of-life communications.<sup>131</sup> In support of this framework, the FCC noted that the DSRC service band plan and transmission standard established a “control channel” in the center of the band. All DSRC radio devices are to “listen” to the control center prior to transmitting. Consequently, the control channel is able to implement the FCC’s priority messaging framework through its “priority interruption capability.”<sup>132</sup> Accordingly, in adopting the DSRC service rules, the FCC recognized a category of “safety” communications that required prioritization above even traditional public safety communications (i.e., those transmitted by public safety eligible). This is particularly important and precedential for the use of autonomous vehicles as the use of communications for safety (such as collision avoidance) would certainly be required and not limited by the class of user or vehicle (i.e., police or other public safety vehicles).

*2. Interference Mitigation and Resolution*

Even where there is not a formal frequency coordination process for a wireless service, there are several interference mitigation and resolution techniques, some of which are automated, that can serve to identify and resolve potential interference between licensees *prior* to deployment.

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130. DSRC Rules Order, *supra* note 21, ¶ 32.

131. *Id.* ¶ 33.

132. *Id.* ¶¶ 30–31.

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Resolution of interference problems after systems are deployed and operating is costly and time consuming. There is an administrative process at the FCC for resolving interference disputes, but the process is lengthy, cumbersome and not the most efficient use of the FCC's—and licensee's—limited resources. Identifying and resolving potential interference problems prior to system deployment is less costly and time consuming, and should not implicate FCC involvement. Below is a description of several interference mitigation and resolution techniques.

*i. Automated Software Review*

Where a wireless service calls for site-specific licensing, an automated software analysis can be required of all applicants. Upon entering the proposed site information, and related technical information, the software can be written to identify potential interference conflicts with incumbent licensees and, with sufficient input, guide applicants away from potential conflicts.<sup>133</sup> Registration and clearing via the software is required as a condition of the receipt of the license.

*ii. Channel Registrations*

In a shared band environment, (i.e., where all licensees have equal access to the spectrum band), another active spectrum management technique is for licensees to be directed to register for specific channels within the band for the service and locations they are deploying. For licensees deploying subsequently at the same or nearby sites, they would register for other channels in the band, thus minimizing the risk of potential interference while enabling the deployment of licensees in close physical proximity to one another.

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133. The DSRC service rules call for the registration of the locations of a licensee's fixed sites within its authorization geographic area in the FCC's Universal Licensing System; however, the FCC's database does not include any sort of automated analysis to identify potential interference that may be caused by a proposed site. See 47 C.F.R. § 90.375(b).

*iii. Third Party Database Manager*

Similar to the coordinators described above for fixed microwave and fixed satellite services licensees, a private, third party entity or entities could be named by the FCC to maintain the database(s) for licensees to register their fixed sites.<sup>134</sup> Such a database could include the active software analysis or other techniques described above. In addition, such a third-party could perform a preliminary review of the applicant's proposed service to ensure that it is consistent with the service definition and other requirements. This minimal review by an independent third party is another mechanism to lessen the likelihood of interference prior to deployment and operation of a system.

*iv. Access Priority*

As described above, the FCC adopted a message priority framework for the DSRC band: safety-of-life messages have the highest priority followed by public safety messages. Consistent with this framework, the FCC also specified that potential interference disputes involving safety of life and public safety communications are to be resolved based on the same priority hierarchy.<sup>135</sup>

*v. Technical and Physical Mitigation Measures*

When locating a new wireless facility, there may be technical and physical mitigation techniques that can mitigate the potential for interference. For example, reducing transmission power or using directional antennas (pointing away from another licensee's facility) can reduce the risk of interference. Physical barriers, such as shielding by some sort of wall or enclosure, are also possible options for protecting one licensee's operations from another. These techniques are site-specific and can be identified from the various aforementioned analyses.

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134. In 2005, the FCC adopted a third party database model for "millimeter wave" point-to-point fixed microwave "links" in the 71–76 GHz and 81–86 GHz bands. Before registering specific sites, licensees are required to provide an interference analysis showing that the proposed link will neither receive from nor cause interference to previously registered links. Allocations and Service Rules for the 71–76 GHz, 81–86 GHz, and 92–95 GHz Bands, Memorandum Opinion and Order, WT Docket No. 02-146, 20 FCC Rcd. 4889, ¶ 12 (2005).

135. DSRC Rules Order, *supra* note 21, ¶ 61.

*vi. Considerations for Autonomous Vehicles*

In any shared spectrum environment, the key to resolving instances of harmful interference is to have information regarding the location and operations of each service's transmitters. Having this information beforehand, that is, before new systems and devices are deployed, greatly minimizes the risk of harmful interference by identifying and avoiding the potential interference in the first place. In whatever spectrum band that autonomous vehicles is expected to utilize, a comprehensive analysis should be conducted before actual deployment to ascertain the spectrum sharing environment and the risk of harmful interference. This analysis will identify what steps need to be taken, by both autonomous vehicles and/or the shared service(s), but whether the risk of interference to the critical safety-of-life messages that will support autonomous vehicles. If the risk is too high, the band may not be appropriate for autonomous vehicles.

### III. INTEROPERABILITY AND STANDARDS

The market for automobiles and other vehicles is international. Automobiles manufactured in the United States are comprised of parts manufactured in Mexico, Canada, and elsewhere. A car manufactured in the United States may be sold in just about any other country. Once sold, vehicles are driven or shipped all over the world. Developers of autonomous vehicle technologies and services, whether they be the vehicle manufacturers themselves, equipment suppliers, software designers, or others, will want to have access to the largest possible market (i.e., the global market). A global market for autonomous vehicles should reduce development, deployment, and marketing costs, resulting in lower costs for consumers purchasing these vehicles. Two key concepts—interoperability and technical standards—if implemented, should help realize the potential global market for autonomous vehicles.

*A. Interoperability*

For communications networks, “interoperability” is the fundamental characteristic to ensure that information can be disseminated to the largest number of users, thus achieving

the largest possible market for the service and the attendant benefits this brings. Interoperability within a wireless communications service, moreover, should enable communication among devices regardless of location, licensee or equipment maker.<sup>136</sup> Interoperability is particularly critical where the wireless service in question supports safety-of-life/public safety communications. In other words, public safety entities—police, fire, emergency medical and others—must be technically able to communicate with each other, across agencies, devices, and across multiple frequencies.<sup>137</sup>

### *B. Technical Standards*

Interoperability is often best achieved by adhering to a common technical standard. In some instances, an industry group, such as a trade association, will reach a consensus that development and use of a common standard will benefit the industry as a whole and members individually. Use of a single standard can provide certainty to manufacturers and consumers that investments in a given technology will not be rendered obsolete by a subsequent, different technology, which is especially true where a new technology is being introduced. Standard compatibility reduces the need to buy duplicative equipment or special devices to convert from one manufacturer's proprietary standard to another's, the so-called "stove pipe" problem. The lack of a common standard may cause manufacturers and consumers to adopt a "wait-and-see" approach before making or purchasing devices. Conversely, using a single standard can deter new technical innovations and improvements, thus "locking in" a less than optimal technology. Competition may also be reduced because product developers are not able to compete as effectively on the basis of different technologies; however, other forms of competition—price, service, and product features—may be enhanced where a single standard is used.

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136. *Id.* ¶ 14.

137. The FCC defines interoperability in its rules as: "An essential communication link within public safety and public service wireless communications which permits units from two or more different entities to interact with one another and to exchange information according to a prescribed method in order to achieve predictable results." 47 C.F.R. § 90.7.

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For communications technologies and services, the FCC's general policy is not to require compliance with a single standard, except where a standard may prove necessary to limit interference between systems.<sup>138</sup> The FCC generally relies on market forces (i.e., competition) to determine the appropriate balance between the technical attributes of a device or service and its cost.<sup>139</sup> However, the FCC may prescribe a standard when compelled to do so by the public interest. In previous instances, the FCC has noted that the "traditional rationale" for requiring a standard is: (1) if there would be a substantial public interest" from a standard,<sup>140</sup> and (2) private industry must be unwilling or unable to reach an agreement on a single industry standard because there are too many competing standards or the costs for private industry to engage in the standards-setting process are too high.<sup>141</sup> These conditions are not exclusive. The FCC may find, for example, that the fact that industry has reached agreement on a single standard argues in favor of requiring a standard. In addition, the benefits to be gained by requiring a standard, especially in terms of lower costs and new and better services to consumers, compel this step. Regardless of the rationale, where the FCC does prescribe a standard, the agency prefers to prescribe "performance" standards that identify the capabilities that are to be achieved, rather than extensive technical standards that may have the effective of "locking in" a particular technical solution that may hinder further advances.<sup>142</sup> On this latter point, the FCC may require that future updates to an adopted standard be backwards compatible to support earlier implementations of the standard.<sup>143</sup>

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138. See *In re* The Development of Operational, Technical and Spectrum Requirements for Meeting Federal, State and Local Public Safety Agency Communication Requirements through the year 2010, Establishment of Rules and Requirements for Priority Access Service, 14 FCC Rcd. 152, ¶ 132 (1998).

139. *Id.* ¶ 118.

140. See *In re* Advanced Television Systems and Their Impact Upon the Existing Broadcast Service, 11 FCC Rcd. 6235, ¶ 31 (1996).

141. *Id.*

142. See *In re* Revision of the Commission's Rules to Ensure Compatibility with Enhanced 911 Emergency Calling Systems, 11 FCC Rcd. 18676, ¶ 73 (1996).

143. See, e.g., Dedicated Short-Range Communications Services, *supra* note 46, ¶ 20 (requiring backwards compatibility for the adopted DSR standard).

By example, the FCC adopted a single transmission standard for DSRC operations, for both roadside radios and on-board vehicle radios, for four stated reasons: interoperability, robust safety/public safety communications, to promote deployment while reducing costs, and consistency with congressional intent.<sup>144</sup> These four reasons are further described below:

- **Interoperability.** The FCC noted that the goal of the DSRC service is to equip every vehicle on the road with a DSRC radio unit that would communicate with a roadside infrastructure.<sup>145</sup> According to the FCC, “[w]ithout an interoperability standard that enables units to communicate with one another regardless of location, equipment used, or the licensee, the overall effectiveness of the national DSRC operations would be drastically reduced.”<sup>146</sup>
- **Robust safety/public safety communications.** According to the FCC, a single transmission standard would support timely and reliable communications, especially for vehicle-to-vehicle and intersection collision avoidance applications, and to prevent interference to these communications.<sup>147</sup>
- **Promote deployment of nationwide DSRC-based ITS applications.** The FCC agreed with commenters who argued that a single transmission standard would reduce overall implementation costs and accelerate deployment, reducing the risk of creating a fragmented market for DSRC services and applications that are not interoperable.<sup>148</sup>
- **Consistent with Congressional intent.** Adoption of a single transmission standard, according to the FCC, was also consistent with congressional intent to have a single standard for DSRC operations.<sup>149</sup>

It is worth noting, in addition, that the adopted standard was based on an existing wireless family of standards, IEEE

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144. DSRC Rules Order, *supra* note 21, ¶ 13. The standard was adopted into the FCC’s Rules at 47 C.F.R. § 90.379 (2010).

145. DSRC Rules Order, *supra* note 21, ¶ 14.

146. *Id.*

147. *Id.* ¶ 15.

148. *Id.* ¶ 16.

149. *Id.* ¶ 17.

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802.11 and 802.11a, which is the transmission standard for wireless broadband, and resulted from a “rigorous and concerted effort” and consensus among a “broad cross section” of international, scientific, manufacturing, and users.<sup>150</sup> Moreover, the adopted standard provides for “backward” compatibility, thus it will not “unduly restrict” future innovation.<sup>151</sup>

There are a multitude of standards-setting organizations that address nearly all aspects of modern life: telecommunications, manufacturing, electronics, construction, security systems, quality control, and management, among others. More generally, standards deal with products, processes, services, systems, or personnel. In the United States, the American National Standards Institute (ANSI) is the national umbrella organization for standards development. ANSI itself does not develop standards; with more than 200 members, ANSI-accredited standards-development organizations have agreed to abide by the key ANSI requirements for the standards-setting process:

- Transparent and consensus-based process;
- Balance of interests among participants;
- Good faith consideration of all views and objections;
- Open participation from materially affected and interested parties; and
- Appeals process.<sup>152</sup>

Most other countries have established counterparts to ANSI to serve the same accreditation and process-setting role. There are regional standards organizations, such as the European Committee for Standardization (CEN), which, different than ANSI, does establish specific standards.

There are also international standards-setting organizations. The International Standards Organization (ISO) is made up of the national standards bodies, such as ANSI. Another significant international standards-setting organization is the International Telecommunications Union

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150. *Id.* ¶ 19.

151. *Id.* ¶ 20.

152. *About ANSI*, ANSI.ORG, [http://www.ansi.org/about\\_ansi/introduction/introduction.aspx?menuid=1](http://www.ansi.org/about_ansi/introduction/introduction.aspx?menuid=1) (last visited May 14, 2012).



(ITU), which is a permanent United States agency. National governments are members of ITU.<sup>153</sup> A key activity of international standards-setting organizations, such as ISO, is to “harmonize” differing standards on the same subject by differing standards-setting organizations around the world.<sup>154</sup> A prominent goal of harmonization is to promote the interoperability of devices and services around the world, thus promoting trade and economic development.

In the telecommunications sector, another key standards-setting body is the IEEE (Institute of Electrical and Electronics Engineers). For example, the family of standards for wireless broadband (802.11) are IEEE standards. The standard adopted by the FCC for the DSRC service was initially developed by the American Society for Testing and Materials, although it is also based on the IEEE 802.11 family of standards.<sup>155</sup>

### CONCLUSION

Access to sufficient and reliable spectrum will be a critical need for autonomous vehicles, especially as these vehicles will rely on wireless technologies to support critical safety applications, such as vehicle collision avoidance. Identifying the most appropriate spectrum environment for autonomous vehicles requires an understanding of the regulatory framework in which spectrum is allocated, assigned, and managed to ensure that spectrum is utilized in a manner that serves the public interest. Defining this regulatory framework must take into account complex legal, public policy, and technical considerations.

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153. As its name implies, the ITU is concerned with communications and information technologies. *What Does ITU do?*, ITU.INT, <http://www.itu.int/en/about/Pages/whatwedo.aspx> (last visited May 14, 2012). The ITU manages and coordinates international use of radio spectrum and satellite orbits, as well as establishing telecommunications standards. *Id.*

154. See generally Salil Deshpande & John W. Nazemetz, *Global Harmonization of Standards*, OKSTATE.EDU, [http://www.okstate.edu/ind-engr/step/WEBFILES/Papers/Global\\_Harm\\_index.html](http://www.okstate.edu/ind-engr/step/WEBFILES/Papers/Global_Harm_index.html) (last visited May 14, 2012).

155. AM. SOC’Y FOR TESTING AND MATERIALS, E2213-03, STANDARD SPECIFICATION FOR TELECOMMUNICATIONS AND INFORMATION EXCHANGE BETWEEN ROADSIDE AND VEHICLE SYSTEMS - 5 GHz BAND DEDICATED SHORT-RANGE COMMUNICATIONS (DSRC) MEDIUM ACCESS CONTROL (MAC) AND PHYSICAL LAYER (PHY) SPECIFICATIONS (2003).

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Autonomous vehicles may rely on several wireless communications services, including satellite, GPS, radar, and short-range communications (i.e., Dedicated Short-Range Communications), none of them were designed specifically to support autonomous vehicles. They each operate in different spectrum bands and have different technical characteristics, procedural requirements, and limitations, which may or may not be consistent with the spectrum needs for autonomous vehicles.

The success of autonomous vehicles will depend on having access to sufficient and reliable spectrum capacity to meet current and future use, and under conditions that ensure an RF environment free of harmful interference from other wireless services. Creating the necessary RF environment for autonomous vehicles should consider the allocation of spectrum bands for wireless services, how spectrum rights are assigned to individual licensees, as well as spectrum management and interference mitigation techniques. A successful spectrum strategy for autonomous vehicles will be essential to supporting a robust and ubiquitous deployment for this new technology.